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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A61B 5/00	A1	(11) International Publication Number: WO 98/08431
		(43) International Publication Date: 5 March 1998 (05.03.98)

(21) International Application Number: PCT/GB97/02307

(22) International Filing Date: 27 August 1997 (27.08.97)

(30) Priority Data:
9617915.5 28 August 1996 (28.08.96) GB

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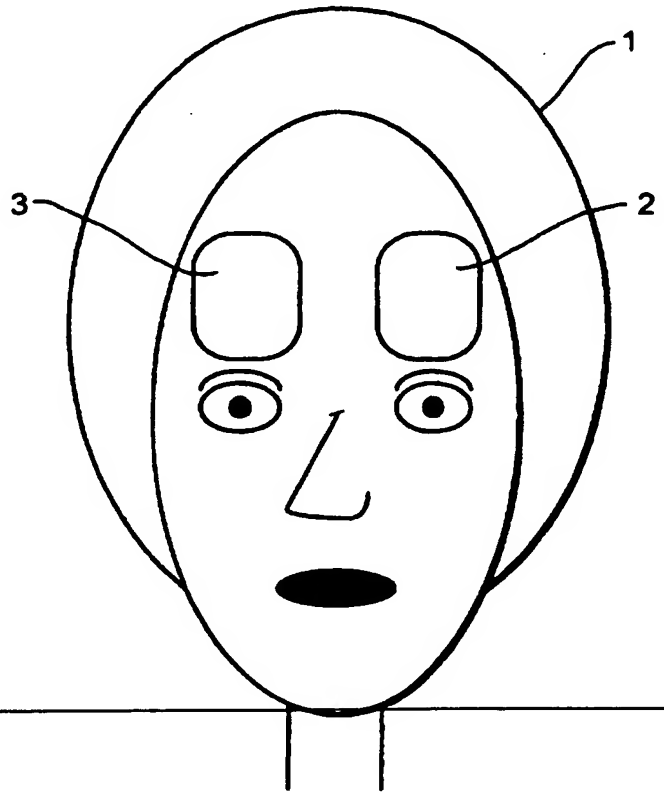
(81) Designated States: AU, CA, IL, JP, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR DETERMINING STRESS

(57) Abstract

Stress in a subject is indicated by measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the subject, correlating said difference against a sample data set of mean baseline resting values, and providing a signal if the temperature difference deviates from said data set by at least a predetermined amount or within a predetermined range. The method permits of lie detection and security screening by the non-invasive measurement of the left and right sides of the forehead and determining whether the differential temperature between the two sides is within first or second predetermined temperature ranges depending upon whether the left side is cooler or warmer than the right side.



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METHOD AND APPARATUS FOR DETERMINING STRESS

The present invention relates to a method of and apparatus for determining stress and has particular application to polygraphy or lie detecting.

Various methods of polygraphy are known. Conventional methods have used measurements of the subject's heart rate and perspiration rate, for example, as an indicator of when the subject might be lying or attempting some deceit. Measuring instruments are attached to the subject's body to obtain the desired measurements. Such techniques are not generally of much use when security screening of a high throughput of people is required. Security screening of this kind is often required at airports and ferry ports, for example, and it is desirable not to alert the subjects to the fact that they are being screened.

In airports or ferry ports, much reliance is based on the members of staff who carry out the security screening. Such members of staff, through experience, may be able to identify potential terrorists or smugglers by the activities of such persons. A terrorist or smuggler might look nervous, for example, and may display the well known symptoms of nervousness. However, this method is reliant on the experience and vigilance of the port staff to detect any potential terrorist or smuggler. Furthermore, experienced terrorists or smugglers can disguise any nervousness and appear perfectly normal and therefore not be detected because of any nervous behaviour.

It is also desirable to carry out security screening in a manner which is non-invasive (i.e. does not involve physical contact with the subject) so that innocent persons are not troubled by the screening process.

It has been reported, for example in Tomarken et al (J. Personality and Social Psychology 1990 59 791-801) that there is a relationship between asymmetrical activity in the anterior regions of the cerebral hemispheres and emotion. Tomarken et al recorded electroenchepalographic (EEG) asymmetry for adult females at rest and after viewing film clips selected to produce neutral, positive or negative affects (viz. interest, happiness, amusement, sadness, anger, fear and disgust). They observed a strong relation between frontal asymmetry and fear responses to film which was independent of the subject's mood rating at the time at which baseline EEG was measured and concluded that resting EEG asymmetry recorded from mid-frontal sites significantly predicted affective responses to film clips.

Kagan et al (Neuropsychology 1995, 9, 47-51) reported the non-invasive determination of forehead temperature of 21-month-old children using an infrared telethermographic scanner. A software program permitted a coder to superimpose boxed areas on stored thermographic images to record mean temperatures within spaced left and right forehead areas. It was found that the distribution of asymmetries in forehead temperature was in accordance with EEG activation data and that the ratio (2:1) of children who were cooler on the left forehead compared with the right forehead was close to the ratio of adults that show greater desynchronization of alpha frequency on the left frontal area compared with the right frontal area. It is suggested that temperature asymmetry is of potential value in studying physiological correlates of cerebral asymmetry and to determine heart rates in children made anxious by application of the cap and electrodes required for recording EEG data.

The present Inventor has now found that forehead temperature symmetry changes can be used to indicate when a

subject is under stress produced, for example, by lying or seeking to evade detection as a terrorist or smuggler. In particular, it has been found that, for at least a substantial proportion of the population, such stress results in a detectable quantitative deviation from a sample data set of mean baseline resting values, which deviation is dependent upon the identity of the cooler side of the forehead.

According to its broadest method aspect, the present invention provides a method of determining whether a person is under stress, the method comprising measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person, correlating (e.g. comparing) said difference against a sample data set of mean baseline resting values, and providing a signal if the temperature difference deviates from said data set by at least a predetermined amount or within a predetermined range.

In the corresponding broadest apparatus aspect, the present invention provides an apparatus for determining whether a person is under stress, the apparatus comprising differential temperature measuring means for measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person; correlation means for correlating said difference against a sample data set of mean baseline resting values; and signal output means providing a signal if the temperature difference deviates from said data set by at least a predetermined amount or within a predetermined range.

In a presently preferred method aspect, the present invention provides a method of determining whether a person is under stress, the method comprising the steps of:

measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person;

correlating said difference against a predetermined temperature range; and

providing a signal indicative of a temperature difference within said temperature range.

In the corresponding preferred apparatus aspect, the present invention provides an apparatus for determining whether a person is under stress, the apparatus comprising:

differential temperature measuring means for measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person;

correlation means for correlating said difference against a predetermined temperature range; and

signal output means providing a signal indicative of a temperature difference within said temperature range.

Presently, the only skin portions determined by the Inventor which are subject to asymmetrical temperature changes in response to emotional stimulus are the left and right side of the forehead but simple experimentation will reveal if there are other symmetrically located skin portions, such as the ears or cheeks, which also exhibit this phenomenon. In order to enable non-invasive temperature measurement to be made under normal circumstances, it is preferred that the skin portions are selected from those which are exposed when wearing conventional daily-wear clothing. Conveniently, the

temperatures of the respective parts are measured with an infra-red camera having its output connected to, for example, a digitiser for digitising the output of the camera.

The temperature difference may be determined and correlated using a neural net.

In most people, it is found that the left side of the forehead is naturally cooler than the right side. In others, the left side of the forehead is warmer than the right side. In either case, if the person is under stress, it is understood that there is an increased right frontal lobe activity. It is believed that this causes the left side of the forehead to become relatively warmer compared to the right side when the person is under stress. This can occur if the person is lying or attempting to smuggle illegal substances for example.

If, as in the case of forehead asymmetrical temperature differences, some people normally have under (non-stressful) resting conditions a left side skin portion cooler than the symmetrical right side skin portion whilst others have the right side skin portion cooler than the left side skin portion, a data set is provided for each type.

The signal can be an audio or visual alarm, the electronic, photographic or other recordal of an image of the person for storage or onward transmission to a location downstream of that at which the temperature measurement is made, or a signal to trigger such recordal. For example, the temperature could be surreptitiously made by non-invasive thermoimaging during departure from an aeroplane, ship or other vehicle or at a passport or other identity checking location and the image transmitted to customs,

immigration or police authority at a downstream passenger location.

In a presently preferred method embodiment, the present invention provides a method of determining whether a person is under stress, the method comprising the steps of:

measuring a difference in temperature between the left and right sides of the person's forehead;

if the left side is cooler than the right side, correlating said difference against a first predetermined temperature range or, if the right side is cooler than the left side, correlating said difference against a second predetermined temperature range; and

providing a signal indicative of a temperature difference within the relevant temperature range.

In the corresponding preferred apparatus embodiment, the present invention provides an apparatus for determining whether a person is under stress, the apparatus comprising:

differential temperature measuring means for measuring a difference in temperature between the left and right sides of the person's forehead;

correlation means for correlating said difference against a first predetermined temperature range when the left side is cooler than the right side, and for correlating said difference against a second predetermined temperature range when the right side is cooler than the left side; and

signal output means providing a signal indicative of a temperature difference within the relevant temperature range.

Said first predetermined temperature range (as measured by three-dimensional thermography) may be 0.10°C to 0.12°C and said second predetermined temperature range

(as measured by three-dimensional thermography) may be 0.15°C to 0.17°C. Corresponding ranges apply when measured by less accurate two-dimensional methods such as those of the initial experiments reported below.

The present invention also includes methods of polygraphy and methods of security screening using the methods described above.

The invention further includes polygraphy apparatus and security screening apparatus including the apparatuses described above.

The following is a description by way of example only and with reference to the accompanying drawings of a presently preferred embodiment of the present invention. In the drawings:

Fig. 1 is a schematic view of apparatus according to a presently preferred embodiment of the present invention;

Fig. 2 is a schematic diagram showing a person's face; and,

Fig. 3 is a section of a three-dimensional temperature contour map of a person's forehead.

It has been found that people normally have temperature differences between the left and right sides of the forehead. In a sample experiment, the temperature of the left and right sides of the forehead was measured for two hundred people. The maximum difference between the left and right forehead temperature was recorded for each subject.

The subjects were sat in a darkened room which was maintained at a constant temperature of 22.5°C. EEG electrodes were connected to monitor the subject's heart rate. The subject was interviewed for five minutes on a

number of non-threatening subjects, such as hobbies and interests, and the weather. It was found that some two thirds of the subjects had cooler left foreheads than right foreheads. The mean maximal forehead temperature asymmetry was measured to be 0.22°C with a standard deviation of 0.03°C for these subjects. For the one third of subjects who had cooler right foreheads than left foreheads, the mean maximal forehead temperature asymmetry was measured to be 0.10°C with a standard deviation of 0.02°C.

It was found from this sample that gender, ethnic background and age of the subjects did not significantly affect the maximal forehead temperature asymmetry.

The experiment was then repeated using the same subjects who were asked to attempt to deceive an interviewer. As in the first experiment, each subject was sat in a darkened room which was kept at a constant 22.5°C. EEG electrodes were connected to monitor the subject's heart rate. The subject in each case was interviewed for five minutes, during which time they were asked to conceal information from the interviewer. During the interview, the maximum difference between left and right forehead temperatures was recorded.

It was found that a subject's heart rate was higher when trying to deceive the interviewer than when answering neutral experiences as in the first experiment. For those two thirds of the subjects having cooler left foreheads than right, the mean maximal forehead temperature asymmetry decreased to 0.14°C with a standard deviation of 0.02°C. For the one third of subjects having cooler right forehead temperatures than left, the mean maximal forehead temperature asymmetry was found to have risen to 0.15°C with a standard deviation of 0.02°C.

It is believed that the right frontal lobe of the brain shows increased activity when a person is lying or otherwise trying to deceive an interviewer. This would explain why the left side of the forehead increases in temperature relative to the right side of the forehead during lying, i.e. when the subject is under stress. This is because the activity of the right frontal lobe is known to excite the heart rate. Possibly blood flow is directed to the right side of the brain so there is a dilation of the blood vessels relative to those in the left hemisphere of the brain. This causes more blood to flow to the right hemisphere than to the left, resulting in the temperature of the left hemisphere increasing.

The apparatus for measuring the forehead temperatures included an infra red camera which was focused on the subject's face. The output of the camera was digitised. Using appropriate software, boxes could be outlined on an image of the subject's forehead in similar manner to that reported in Kagan et al (supra). This is shown in Figure 2. In Figure 2, an image 1 of a subject's face has a box 2 drawn for the left side of the forehead and another box 3 for the right side of the forehead. The use of such boxes 2,3 allows regions outside of the half of the forehead being studied to be included or allows regions from the half of the forehead being studied to be excluded, at will. This allows errors in the obtaining of temperatures on the sides of the forehead to be eliminated or at least reduced to a minimum.

Furthermore, by using a three-dimensional contour map of a thermograph of the subject's face, the edges of the left and right forehead regions could be more clearly identified because they were surrounded by regions of lower temperature. This is shown in Figure 3, which is a section through a portion of the three-dimensional temperature

contour map. This clearly shows the high temperature regions corresponding to the boxes 2,3 on the subject's face.

The results obtained in the two experiments mentioned above were reanalysed using three-dimensional contour plots to find more accurate temperature differences and standard deviations. It was found that for people having a cooler left forehead than right, the mean maximal forehead temperature asymmetry was 0.15°C with a standard deviation of 0.015°C when the subject was not lying. For people having a cooler right forehead than left, the mean maximal temperature asymmetry was found to be 0.12°C with a standard deviation of 0.01°C when the subject was not lying.

When the subject was lying, using the three-dimensional contour map approach, for people having a cooler left forehead than right, the mean maximal temperature asymmetry was found to be 0.11°C with a standard deviation of 0.01°C. When lying, for people having a cooler right forehead than left, the mean maximal temperature asymmetry was found to be 0.16°C with a standard deviation of 0.02°C.

A particular application for the present invention is for polygraphy generally and especially for security screening, for example at high security buildings or in airports, ferry ports, or other ports. Typical apparatus is illustrated in Figure 1.

In Figure 1, an infra red camera 10 has its output connected to a digitiser 11. The infra red camera 10 is arranged to be focused on faces of subjects as they go past a check-in desk 20, for example. The apparatus may be arranged such that it is not visible to people walking past

so that they are not aware of the screening process taking place.

The digitiser 11 converts the output from the camera 10 into digital form for analysis by a computer or other data processor 12 connected to the output of the digitiser 11. The data processor might be an expert system or neural net, for example.

The computer 12 processes the information from the digitiser 11. In particular, under software control, the computer 12 identifies the regions 2,3 of the left and right sides of the forehead of the subject 1 and calculates the temperature difference between the left and right sides. This may be done by averaging ten images taken over a short period for the particular subject 1. The boxes 2,3 can be identified by the computer 12 by analyzing a three-dimensional temperature contour map of the subject's face. The boxes 2,3 can be identified as they are bounded by distinct regions of lower temperature as indicated in Figure 3. For example, the temperature measured over the subject's face can be differentiated over the entire surface and the edges 4 of the hot parts of the subject's forehead corresponding to the boxes 2,3 can be identified by the rapid change in slope as indicated in Figure 3.

The temperature difference between the two sides of the forehead is then calculated. This may be done by subtracting the temperature of the right forehead from that of the left forehead. The average of ten images can then be calculated.

If the value is positive (i.e. the left side is warmer than the right side) and in the range of 0.15°C to 0.17°C, then an alarm can be signalled on a screen of a visual display unit 13 to which the computer 12 is connected.

This alerts security staff who can take appropriate action if necessary.

If the value is negative (i.e. the left side is cooler than the right side) and in the range of 0.10°C to 0.12°C, then an alarm signal is again displayed on the screen of the visual display unit 13.

Of course, when an alarm signal is sent to the screen 13, an audible alarm can also be produced if required. Furthermore, an image of the face of the subject concerned can be displayed on the screen 13. Details of the subject concerned, including an image of the face, might be sent to some central security processing station for example.

An embodiment of the present invention has been described with particular reference to the example illustrated. However, it will be appreciated that variations and modifications may be made to the example described within the scope of the following claims.

CLAIMS:

1. A method of determining whether a person is under stress, the method comprising measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person, correlating said difference against a sample data set of mean baseline resting values, and providing a signal if the temperature difference deviates from said data set by at least a predetermined amount or within a predetermined range.

2. A method as claimed in Claim 1, wherein said method comprises the steps of:

measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person;

correlating said difference against a predetermined temperature range; and

providing a signal indicative of a temperature difference within said temperature range.

3. A method as claimed in Claim 1 or Claim 2, wherein, under resting conditions, said left side skin portion or said right side skin portion can be cooler than the other side portion, depending upon the subject, and a said data set is provided for each type.

4. A method as claimed in Claim 3, wherein said skin portions are at left and right sides of the forehead.

5. A method as claimed in Claim 4, wherein said method comprises the steps of:

measuring a difference in temperature between the left and right sides of the person's forehead;

if the left side is cooler than the right side, correlating said difference against a first predetermined temperature range or, if the right side is cooler than the left side, correlating said difference against a second predetermined temperature range; and

providing a signal indicative of a temperature difference within the relevant temperature range.

6. A method as claimed in Claim 5, wherein (as measured by three-dimensional thermography) said first predetermined temperature range is 0.10°C to 0.12°C and said first predetermined temperature range is 0.15°C to 0.17°C.

7. A method as claimed in any one of the preceding claims, wherein the temperature is measured without physical contact with the subject.

8. A method as claimed in Claim 7, wherein the temperature is measured by thermoimaging.

9. A method as claimed in any one of the preceding claims, wherein the signal comprises or triggers the electronic, photographic or other recordal of an image of the person for storage or onward transmission to a location downstream of that at which said temperature measurement is made.

10. A method of lie detection comprising determining stress by a method as defined in any one of the preceding claims.

11. A method of security screening comprising determining stress by a method as defined in any one of Claim 1 to 9.

12. An apparatus for determining by a method as claimed in Claim 1 whether a person is under stress, the apparatus comprising differential temperature measuring means for measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person; correlation means for correlating said difference against a sample data set of mean baseline resting values; and signal output means providing a signal if the temperature difference deviates from said data set by at least a predetermined amount or within a predetermined range.

13. An apparatus for determining by a method as claimed in Claim 2 whether a person is under stress, the apparatus comprising:

differential temperature measuring means for measuring a difference in temperature between symmetrically located left and right skin portions which are subject to asymmetrical temperature changes in response to emotional stimulus of the person;

correlation means for correlating said difference against a predetermined temperature range; and

signal output means providing a signal indicative of a temperature difference within said temperature range.

14. An apparatus for determining by a method as claimed in Claim 4 whether a person is under stress, the apparatus comprising:

differential temperature measuring means for measuring a difference in temperature between the left and right sides of the person's forehead;

correlation means for correlating said difference against a first predetermined temperature range when the left side is cooler than the right side, and for correlating said difference against a second predetermined

temperature range when the right side is cooler than the left side; and

signal output means providing a signal indicative of a temperature difference within the relevant temperature range.

15. An apparatus as claimed in any one of Claims 12 to 14, wherein said differential temperature measuring means measures temperature without physical contact with the subject.

16. An apparatus as claimed in Claim 15, wherein the differential temperature measuring means measures temperature by thermoimaging.

17. An apparatus as claimed in any one Claim 12 to 16, wherein the signal output means comprises the electronic, photographic or other recordal means for recording an image of the person for storage or onward transmission to a location downstream of that at which said temperature measurement is made.

18. A polygraph comprising apparatus as claimed in any one of Claims 12 to 17.

19. A security screening apparatus comprising apparatus as claimed in any one of Claims 12 to 17.

FIG. 1

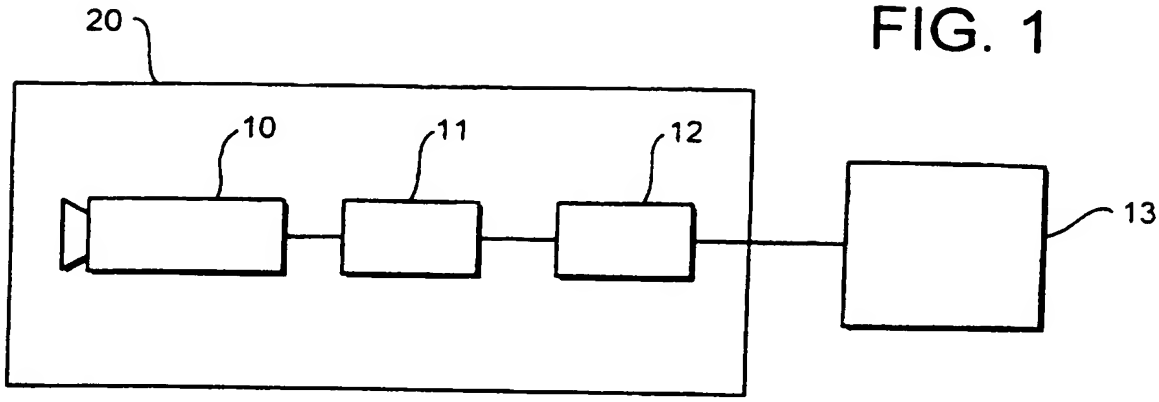
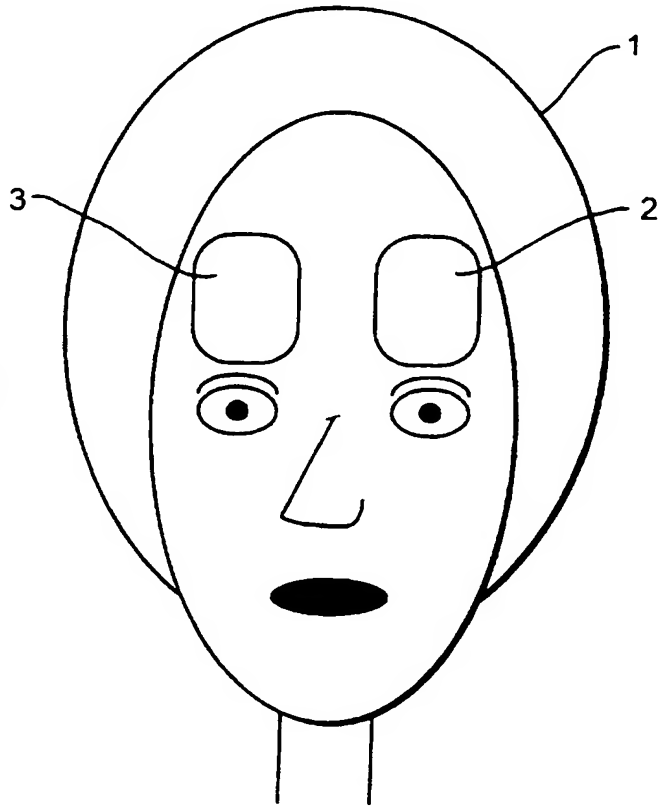


FIG. 2



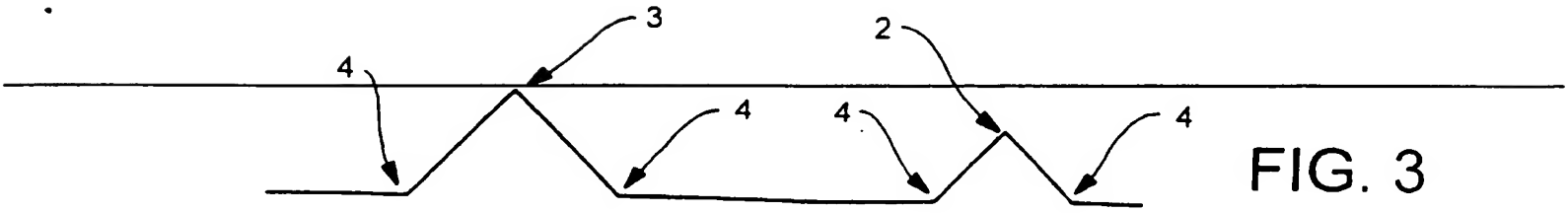


FIG. 3

INTERNATIONAL SEARCH REPORT

Ir. ..national Application No
PCT/GB 97/02307

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B5/00

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 060 657 A (R.A. TEAGUE) 29 October 1991	1
A	see column 1, line 10 - line 23	2,3,5
A	see column 2, line 49 - line 59	9,12-14
A	see column 3, line 58 - column 5, line 22	17
X	US 4 428 382 A (E.P.T. WALSALL ET AL.) 31 January 1984	1-3,7,8
X	see column 3, line 5 - line 35	12,13, 15,16
A	see column 6, line 8 - column 7, line 65	5,14

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 December 1997	16/01/1998

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 97/02307

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	J. KAGAN ET AL.: "Asymmetry of Forehead Temperature and Cardiac Activity" NEUROPSYCHOLOGY, vol. 9, no. 1, 1995, pages 47-51, XP002050262 cited in the application see page 48 - page 49; figure 1	1-5,7-9, 12-17
A	WO 94 05206 A (J. BOCZAN) 17 March 1994	1-3
A	see page 3, line 1 - line 27 see page 4, line 3 - line 19 see page 5, line 23 - line 34 see page 7, line 9 - line 37	12,13

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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US 4428382 A	31-01-84	NONE	
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